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Effects of Oil Field Development on Calf Production and Survival in the Central Arctic Caribou Herd

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SUMMARY

We measured rates of survival, growth, and weight gain of caribou (*Rangifer tarandus*) calves from the Central Arctic Herd (CAH) from June 2001 through September 2003 as part of a 5-year study of potential effects of increasing levels of anthropogenic disturbance during the calving period. Calves were captured and radiocollared in June of each year in the 2 main calving areas of the CAH, located east and west of the Sagavanirktok River in northern Alaska. The western calving area is expected to experience increasing levels of disturbance during the study, whereas the eastern area is relatively less disturbed. Radiocollared calves were located at approximately 2-week intervals from June–October to estimate survival. Calves were again captured, weighed, and measured during September and March. Summer distributions of calves from the 2 calving areas were assessed by modeling the 95% fixed kernel utilization distributions of locations from each radiotracking trip. In March 2003, 26 caribou cows were captured and fitted with GPS-equipped collars programmed to determine locations every 5 hours during May–October and every 2 days during November–April. Calves of 17 of these cows were captured and radiocollared in June 2003. Summer ranges of GPS-equipped caribou were determined as the minimum convex polygons enclosing GPS locations obtained from late June–early September.

Kaplan–Meier estimates of calf survival from June–September ranged from 0.74–0.97; annual survival ranged from 0.67–0.71. Ninety-five percent confidence intervals of survival estimates overlapped greatly among years and between calving areas. June weights did not differ between calving areas but did differ among years. September weights and weight gain from June–September were greater for calves from the eastern area and also differed among years. Metatarsus lengths during June were greater for eastern calves and also differed among years. There were no other significant differences in physical measurements due to area, year, or area–year interactions. Although distributions of calves from the 2 calving areas overlapped extensively during summer, calves from both groups usually were found in the area where they

were born, and eastern calves showed greater fidelity to the birth area (87% of summer locations were in the eastern area) than did western calves (78% of locations were in the western area). Summer ranges of eastern calves ($\bar{x} = 8958 \text{ km}^2$; $n = 5$) were smaller than ranges of western calves ($\bar{x} = 15,579 \text{ km}^2$; $n = 7$).

Because sampling areas were not randomly determined, comparisons between groups do not imply any cause–effect relationships, and the lack of significant increases in disturbance levels during this period precludes an assessment of disturbance effects at this time. However, these data provide a useful baseline for future comparisons and can be used to suggest hypotheses for further study. The differences we noted were consistent with the hypothesis that caribou habitat in the western area is of lower quality than in the eastern area. However, the rates of calf growth and survival we observed and the increasing trend shown by the CAH since the 1970s suggest that habitat conditions in both calving areas were favorable for caribou. It is unlikely that the herd’s increasing trend will continue indefinitely, however. If the CAH should begin to decline, detailed demographic, physiological, and behavioral data will be needed to address questions regarding the relative importance of environmental and anthropogenic effects. We recommend modifying the study by deploying additional GPS collars so that quantitative models of each calf’s exposure to disturbance can be developed. This will enable statistically valid inferences to be made regarding causes of any changes that are observed in calf growth and survival rates.

Key words: calf growth and survival, caribou, Central Arctic Herd, oil field impacts

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BACKGROUND

The Central Arctic caribou (*Rangifer tarandus*) herd (CAH) has been the subject of research aimed at assessing potential effects of industrial development since the herd was first identified during the 1970s (Cameron and Whitten 1979; Whitten and Cameron 1983a). This is largely because the calving and summer ranges of the CAH encompass the major oil fields near Prudhoe Bay and the lower reaches of the Kuparuk River on Alaska's arctic coastal plain (Fig 1). Most research during the 1980s and 1990s focused on identifying effects of industrial infrastructure (pipelines, roads, drill pads, and related structures) and human activity on caribou movements, activity patterns, and calving distribution. Several studies suggested that, during the calving season (late May–late Jun) pregnant caribou cows and those with newborn calves avoided areas of disturbance associated with oil exploration and extraction (Dau and Cameron 1986; Cameron et al. 1992; Nellemann and Cameron 1996). For example, during the 1990s, the area of greatest concentration of calving by the western segment of the CAH shifted southward as development of oil-related infrastructure occurred in what was originally a major calving area (Lawhead and Johnson 2000; Wolfe 2000). However, caribou bulls and nonpregnant cows may habituate to some levels of oil field activity (Curatolo and Murphy 1986; Pollard et al. 1996) and population-level effects of disturbance have not been demonstrated conclusively (Cronin et al. 1998). In fact, the CAH increased from approximately 5000 caribou in 1975 (Whitten and Cameron 1983b) to almost 32,000 in 2002 (Lenart 2003).

Caribou populations throughout northern Alaska evidently were well below carrying capacity when studies of the CAH began during the late 1970s, and 3 of the 4 arctic caribou herds showed dramatic increases in population size during the 1980s and 1990s (Griffith et al. 2002). Thus, population-level effects of disturbance may have been masked by the herd's responses to weather, range conditions, insect activity, or other environmental factors. The theoretical connections between effects of disturbance on individual caribou and potential effects on the population have been described (Cameron 1983; Murphy and Curatolo 1987; Murphy et al. 2000), and some effects of disturbance may be evident only when combined with other adverse environmental influences (National Research Council 2003). Thus, despite the increase shown by the CAH during the period of oil field development, continuing concerns about effects of anthropogenic disturbance on caribou populations have led to the establishment of mitigation measures to be included in oil field development plans (Cronin et al. 1994) and the exclusion of some areas from petroleum development (U.S. Bureau of Land Management 1998).

Beginning with development of the Meltwater prospect during 2001, the area of industrial activity within the range of the CAH recently has been extended southward along the western side of an area that was used extensively for calving during the 1990s (Fig 1). Although the Meltwater project includes a plan to mitigate possible disturbance to caribou, some displacement of caribou cows may occur during the calving and immediate postcalving periods. Other projects that are likely to occur during 2001–2005, including construction of a major access road, may further extend development into the intensive calving area. In addition, exploration and extraction of oil in the range of the neighboring Teshekpuk caribou herd (TCH) has begun. Environmental permits for these and future developments will likely include stipulations for measures to reduce disturbance of caribou. These requirements will be based largely on studies of the CAH, although significant data gaps remain. Of particular importance are the needs to identify specific physiological effects of disturbance that may be expected to have consequences

for caribou population dynamics, and to evaluate the effectiveness of established mitigation measures.

OBJECTIVES

This study is designed to investigate how increasing levels of anthropogenic disturbance within caribou calving grounds during the 5-year period 2001–2006 may affect production, growth, survival, and movements of caribou calves. The study will focus on physical parameters of calves because these directly influence population growth rates, and are themselves influenced by habitat use and movements of adult caribou cows (Cameron et al. 1993; Cr  te and Huot 1993; Cameron and Ver Hoef 1994). Thus, if anthropogenic disturbance causes caribou cows to alter their activity patterns or use of habitats, these effects should be evident in differing rates of growth and survival of calves. Objectives of the study are to:

- 1 Estimate annual pregnancy and birth rates of caribou cows.
- 2 Estimate survival of caribou calves to yearling age class and determine causes of mortality.
- 3 Estimate rates of growth and weight gain by calves during summer and winter.
- 4 Assess changes in location, physiography, and vegetation of calving sites among years.
- 5 Monitor movements of caribou to determine winter and summer distributions.
- 6 Estimate size of the herd at 2–year intervals using a complete aerial photocensus.

STUDY AREA

The study area encompasses the range of the Central Arctic caribou herd, extending from the Chandalar River drainage in the southern Brooks Range north to the Arctic coast and approximately from longitude 145 to 150° west (Fig 1). Terrain varies from rugged mountains typical of the herd’s winter range to low, flat, arctic tundra typical of calving areas and coastal gravel bars used for summer insect relief. The area is approximately bisected by the Dalton Highway/trans-Alaska Pipeline corridor, and the northern section has undergone extensive industrial development associated with exploration and production of oil and gas resources in the Prudhoe Bay, Kuparuk, and associated oil fields. The remainder of the area is remote and relatively undisturbed by human activity, except for dispersed recreation (hiking, river floating, and hunting).

METHODS

Fieldwork will take place during 2001–2006. This report describes results from 2001–2003 and plans for future work. The Alaska Department of Fish and Game (ADF&G) maintains a sample of approximately 80 radiocollared caribou cows in the CAH. Radiocollared adult (≥ 3 years old) cows were located repeatedly during the calving period (early Jun), 2001–2003, to determine the proportion of cows that were pregnant and the proportion that produced calves. Parturition status of cows that were not observed with calves was assigned according to the presence or absence of

hard antlers and distended udders (Whitten 1995). The distribution of calving caribou cows was determined each year by the 99% fixed kernel utilization distribution of radiocollared parturient cows (those accompanied by calves or judged to be pregnant) during the peak of the calving period (Wolfe 2000; Griffith et al. 2002).

During 2001–2003, 60–65 neonatal calves (≤ 2 days old, as determined by mobility, posture, and presence and appearance of umbilicus) were captured each year. Captures were divided equally between the 2 main calving areas of the CAH, located east and west, respectively, of the Sagavanirktok River (hereafter referred to as eastern and western calving areas). Specific boundaries of the capture areas were determined by the distributions of parturient radiocollared cows in the 2 areas each year (Fig 2). Only female calves were captured during 2001–2002, but 11 male calves were included during 2003. Calves were captured by hand after pursuit with a helicopter. Captured calves were marked with expandable, breakaway radio collars, weighed, and a metatarsus was measured. Locations where calves were captured during early June were photographed and classified according to general habitat characteristics (plant communities, percent snow cover). During early September and March, collared calves were again captured, weighed, and measured. September and March captures were accomplished using a net-gun fired from a helicopter. During March 2002 and 2003, 10 captured calves each year were equipped with adult-sized radio collars to maintain the sample of radiocollared adults.

Collared calves were located by aerial radiotracking approximately twice per month during late June–October, then again during late February and early June of the following year. Deaths of collared calves were recorded based on intervals between radiotracking flights, and survival was estimated using the Kaplan–Meier staggered entry procedure of Pollock et al. (1989) for summer (Jun–early Sep) and for their first year (Jun–May). Whenever possible, carcasses of calves that died were examined and probable cause of death was determined. We examined summer distributions of groups of calves from the 2 calving areas (eastern and western) using the 95% fixed kernel utilization distributions of locations obtained during each radiotracking trip. To reduce bias due to limited mobility of young calves, we restricted this analysis to data from calves that were >2 weeks old. In addition, locations of radiocollared calves and cows during February–March were used to identify wintering areas.

A complete photocensus of the CAH was conducted in July 2002. The census used standard methods for censusing caribou herds in Alaska (Valkenburg et al. 1985); a small fixed-wing aircraft (Piper PA-18) located collared caribou while the herd was aggregated along the Arctic coast. The groups were then photographed using a 9-inch format aerial camera mounted in a DeHavilland Beaver aircraft. Caribou on the photographs were counted and classified as either calves or adults. Additional censuses are planned for July 2004 and 2006.

Future analyses will compare known calving locations (capture sites) and calving distributions (fixed kernel models) with digital habitat data (plant communities, topography, snow cover, plant phenology) to detect potential changes in habitats occupied during the calving and postcalving periods. Data on calf weights and growth rates will be compared over time for each area, to detect temporal trends that may be associated with changes in calving distributions and habitat characteristics.

Our study design assumed that the birth site of a calf would have some influence on the calf's growth and survival, by affecting forage available to the calf's mother during lactation or habitats used by the calf during postcalving and summer, and we hypothesized that anthropogenic disturbance might cause calving distributions to change. However, more subtle effects of disturbance might not be evident in the distribution of calving locations. Thus, in March 2003 we began a pilot project to determine the feasibility of gathering detailed data on movements of caribou cow-calf pairs in summer. These data will be used to develop quantitative models of each pair's use of habitats and exposure to various levels and types of anthropogenic disturbance, weather, and other environmental conditions.

For the pilot project, 26 caribou cows were captured during the first week of March 2003 and equipped with collars containing satellite-linked GPS receivers. These collars were programmed to determine an animal's position at intervals of 2 days during winter (Nov–Apr) and 5 hours during summer (May–Oct). Location data were stored on-board the collars and relayed by satellite uplink once per week during winter and daily during summer. Calves of 17 of these cows were captured, weighed, measured, and equipped with radio collars in June 2003. These included 9 in the western area (5 M; 4 F) and 8 in the eastern area (6 M; 2 F). Of the remaining GPS-equipped cows, 1 died during spring migration, 4 either did not produce a calf or lost the calf soon after birth, 3 had calves that were born late in the calving period (after capture operations had ended), and 1 had a calf that could not be found during capture operations. Calves born after the peak of calving were excluded from this project because these represent a small proportion of each cohort and may have lower survival rates than calves born during the peak of calving (Adams et al. 1995).

We examined performance of GPS collars by comparing fix success rate (number of times the GPS reported its location divided by the number of times it was programmed to do so) during summer (late Jun–early Sep). We assumed that surviving calves of GPS-collared cows always accompanied the cows; thus, GPS data could be used to indicate movements of both cows and calves. This assumption was confirmed by periodic radiotracking flights during summer. Data from the GPS collars were used to determine how well radiotracking data obtained at 2-week intervals represented actual areas used by calves during summer. Because of the short interval between GPS locations (usually 5 hr), we assumed that these data provided an accurate record of each animal's movements during summer. We compared tracking methods using a linear regression with proportions of each animal's GPS locations that were east of the Sagavanirktok River as the independent variable and the same proportions of radiotracking data as the dependent variable. Proportions were transformed using the arc-sine transformation to better approximate a normal distribution (Zar 1984). We determined summer ranges for each GPS-collared caribou as the minimum convex polygons enclosing GPS locations during the period 23 June–7 September.

RESULTS

Parturition rate (the proportion of radiocollared caribou cows ≥ 3 years old that were judged to be pregnant or had given birth) was 91% in 2001 ($n = 35$), 87% in 2002 ($n = 54$), and 96% in 2003 ($n = 54$; Lenart 2003). Snow cover was widespread across the calving area in early June 2001, and as a result, spring migration was slow and calving occurred over a larger area than during most years (Fig 2). The peak of calving in 2001 was approximately 9–10 June; several days later

than during 2002 and 2003 when the peak of calving was approximately 5–6 June. Our model likely overestimated the calving distribution in 2001 because of the lateness of calving; some pregnant cows that were located south of the usual calving areas during the survey (3–9 Jun) probably moved north before giving birth. However, our observations during the capture operation suggested that caribou cows and calves were more widespread than during most years. Snowmelt occurred earlier during 2002 and 2003, so that much of the usual calving area was free of snow by the peak of calving. Calving distributions during these years were similar to other years with similar timing of snowmelt (Fig 2).

Kaplan–Meier survival estimates of calves during June–September 2001–2003 ranged from 0.74–0.86 and from 0.81–0.97 for calves born in the eastern and western areas, respectively (Fig 3). Annual survival for the 2001 and 2002 cohorts was 0.71 and 0.67, respectively, for eastern calves and 0.71 and 0.75 for western calves. Mean weights, weight gain, metatarsus lengths, and growth of calves captured during June and September 2001–2003 and during March 2002 and 2003 are summarized in Tables 1–4. We excluded June data for 11 calves (10 during 2002; 1 during 2003) that were judged to be >2 days old when captured, based on the absence of an umbilicus, appearance of hooves, and mobility. These calves were included in analyses of September data and June–September changes. Mean weights of male ($n = 11$) and female ($n = 49$) calves captured during June and September 2003 differed by <0.07 kg and mean metatarsus lengths differed by <0.40 cm, so data for both sexes were pooled for the 2003 cohort. We tested for effects of calving area, year, and an area–year interaction on data from June and September using analysis of variance. June weights did not differ between areas ($P = 0.43$) but did differ among years ($P < 0.01$). September weights and June–September weight gain were both greater for the eastern area and also differed among years ($P < 0.01$). Metatarsus lengths during June were greater in the eastern area ($P = 0.02$) and also differed among years ($P < 0.01$). September metatarsus lengths and change in length from June–September did not differ either between areas or among years ($P > 0.05$). There were no significant interactions between area and year (all $P > 0.15$). Future analyses will include data from March captures and rates of growth and weight gain between September and March.

Summer radiotracking data indicated that distributions of calves from the 2 calving areas overlapped extensively, beginning in July and increasing during August (Figs 4–6). Fidelity to birth area, defined as the percent of a calf’s radiotracking locations that were on the same side of the Sagavanirktok River as the calf’s birth site, was high and was greater (87%) for calves born in the eastern area than for those born in the western area (78%; arc-sine transformation, $t = 2.25$, $P = 0.03$). Thus, there was some cohesiveness of the 2 calving groups despite their spatial overlap. Mean area encompassed by the 95% kernel utilization distributions for calves from the eastern area (12,233 km²) was less than for calves from the western area (17,350 km²; paired $t = 2.0$, $P = 0.01$). Calves from both areas used the northwestern section of the Arctic National Wildlife Refuge extensively during late summer and fall.

Winter radiotracking surveys were conducted during the last week of February each year. Sixty-one cows and 46 calves were located during 2002, and 65 cows and 35 calves were located during 2003. Sixty percent of radiocollared cows and calves used wintering areas in the southern Brooks Range during 2001–2002; this proportion increased to 80% during 2002–2003 and 2003–2004 (preliminary data from Sep–Oct 2003). Most caribou wintering on the south side of the Brooks Range were located along the southwestern boundary of the Arctic National Wildlife

Refuge (Figs 7 and 8). Smaller numbers of radiocollared caribou wintered in the eastern section of Gates of the Arctic National Park and Preserve, the northern foothills of the Brooks Range, or on the arctic coastal plain. There was no evidence of segregation by calving area among caribou during winter.

A complete photocensus of the CAH was conducted on 16 July 2002, while the herd was aggregated in 9 large groups along the Arctic coast. A total of 31,857 caribou were counted on photographs taken during the census (Lenart 2003).

One GPS collar failed to report any locations after it was first deployed in March 2003. The VHF transmitter on this collar continued to operate, and the pulse rate of the transmissions indicated that the GPS unit was not functioning. One other GPS-collared caribou died during spring migration and was not included in further analyses. Mean fix success rate for the 24 collars operating during summer was 91% of 369 potential fixes. Collars reported at least one fix/day on a mean of 97% of the 77 days during the period. Eighteen collars successfully obtained >90% of potential fixes, and 23 collars reported a fix on >90% of the days during the period. Success rates for 3 collars were <75%; these obtained 55, 58, and 73% of the possible fixes (75, 79, and 94% of days in the period). Data from 12 GPS-collared cows with radiocollared calves that survived through early September were used to test the reliability of our assessment of fidelity to birth areas based on radiotracking data. There was a significant positive relationship between proportions of locations east of the Sagavanirktok River as determined by the 2 tracking methods (arc-sine transformation of proportions; $P < 0.0001$; adjusted $R^2 = 0.92$; Fig 9). The estimated slope (0.95) and intercept (-0.009) of the regression were very similar to a 1:1 relationship. Minimum convex polygon ranges of eastern calves during summer ($n = 5$, $\bar{x} = 8958 \text{ km}^2$; range = 7390–11,289 km^2) were larger than ranges of western calves ($n = 7$, $\bar{x} = 15,579 \text{ km}^2$; range = 12,019–20,656 km^2 ; $t = 4.69$, $P = 0.001$).

DISCUSSION

This study was designed to detect temporal changes in caribou movements, habitat use, growth rates, and survival that might be associated with increasing levels of industrial development in the western calving area. During 2001–2003, the amount of industrial activity within and adjoining the western calving area remained relatively constant; thus, the basic question cannot be addressed until additional development does occur. However, these data provide a useful baseline for comparison to future results. Because the 2 sampling areas used in this study (eastern and western calving areas) were not randomly determined, the scope of inferences that can be made based on comparisons between areas is limited to a description of differences between the 2 groups of animals that were studied (i.e., no cause–effect relationships are implied). However, such comparisons are useful in suggesting hypotheses for future study. Some of the differences we noted between areas are consistent with the conclusion of Wolfe (2000) that habitat currently used for calving by most caribou in the western area is of lower quality than in the eastern area. For example, September weights and rates of summer weight gain were consistently less for calves born in the western area, whereas these calves used larger summer ranges and showed less fidelity to the birth area than eastern calves. This suggests that calves from the western area may have invested more effort in traveling in search of forage, insect relief, or other necessary resources. These differences were small, and did not seem to affect survival; in fact, survival rates were slightly (although not significantly) higher for calves from

the western area. Evidently, habitat conditions throughout both calving areas were of sufficient quality to promote growth and survival of calves. In addition, winter range conditions in the southern Brooks Range were sufficient to allow further growth of calves during winter. The dramatic increase shown by the CAH since 1993 likely is at least partly due to habitat conditions that have led to high reproductive success.

It is impossible to determine whether the shift in calving distribution shown by caribou calving in the western area during the 1980s was a response to industrial development or an effect of the increase in herd size. Thus, the differences we noted between calves from the 2 calving areas do not necessarily imply effects of disturbance. However, our results suggest that there is sufficient variability in habitat quality across the coastal plain to affect growth rates of calves. If further increases in levels of anthropogenic disturbance cause caribou to reduce their use of preferred habitats, it should be possible to detect physiological effects of these changes on growth and survival of calves. If similar changes do not occur in the relatively less-disturbed eastern area, then this may be taken as evidence of possible effects of disturbance. Conversely, if caribou habituate to industrial development or if they simply redistribute their movements around areas of human activity without changing patterns of habitat use, there may be no negative effects.

CONCLUSIONS AND RECOMMENDATIONS

A basic premise of our study design was that the location of a calf's birth site has some influence on habitat use of that calf during summer, and thus may affect the calf's growth and survival. Our radiotracking data support that premise, in that most calves showed high fidelity to the area in which they were born. This conclusion is further supported by the GPS locations obtained every 5 hours, which show close agreement with data from periodic radiotracking. However, logistical constraints limit the amount of radiotracking data that can be obtained, and caribou often move rapidly over relatively long distances during summer, in response to changes in weather and insect activity (Fancy 1983; Murphy and Curatolo 1987). Thus, the more detailed data provided by GPS collars will be extremely valuable in enabling us to model caribou movements in response to a wide variety of stimuli. The GPS data also will allow us to quantify levels of exposure to various types of disturbance without regard to an arbitrary classification of birth site, so that statistically valid inferences can be made regarding potential causes of any changes that occur.

As the CAH increased from approximately 5000 caribou during the 1970s to almost 32,000 in 2002, the areas used both for calving and for winter range also increased. Of particular interest is the dramatic increase in use of the southern Brooks Range for winter habitat, an area that evidently was not used by the herd during the 1970s and 1980s (Cameron and Whitten 1979; Jakimchuk et al. 1987). Growth rates of calves wintering in the southern Brooks Range suggest that forage is abundant and of good quality, as would be expected in an area that had seen little use by caribou for 2–3 decades. As use of this wintering area increases, high-quality forage may become scarce. This would likely reduce caribou survival, spring body condition, and reproductive success (White 1983; Cameron et al. 1993), which could stabilize or reverse the current population trend. If the CAH begins to decline, detailed demographic, physiological, and behavioral data will be necessary to address questions about the relative importance of environmental and anthropogenic effects, to predict the potential importance of development within ranges of other caribou herds, and to recommend effective mitigation methods.

Based on the satisfactory performance of the GPS collars deployed in March 2003, we propose to purchase and deploy 55 additional GPS collars in March 2004. During June 2004–2007 we will capture 60–65 calves of GPS-collared cows. Calves will be weighed and measured in June, September, and March as described above. Periodic radiotracking during summer will be used to estimate calf survival. As soon as funding is secured, we will recruit a PhD student in mathematical ecology to begin development of spatially explicit models of each cow–calf pair’s use of habitats and exposure to anthropogenic disturbance, weather, and other environmental conditions. These models will be used to investigate effects of different levels and types of disturbance on movements and habitat use of calves during summer, and how changes in these parameters may affect rates of growth, weight gain, and survival. These models also will be used to evaluate the effectiveness of mitigation measures that have been employed in the existing oil fields (e.g., raised pipelines and separation of pipelines from roads) and suggest improvements.

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TABLE 1 Weights (kg) of calves from the Central Arctic caribou herd, June–March 2001–2003

Area	Cohort	June			September			March ^a		
		\bar{x}	s	n	\bar{x}	s	n	\bar{x}	s	n
East ^b	2001	6.1	0.9	33	40.9	4.3	24	47.3	6.4	11
	2002	7.0 ^c	1.0 ^c	20 ^c	43.7	4.1	24	47.0	4.9	10
	2003	6.7	1	29	45.8	3.9	23			
West ^b	2001	6.3	0.9	32	39.0	4.3	24	44.6	3.7	14
	2002	6.6	0.9	30	41.4	6.1	26	44.9	3.5	15
	2003 ^d	6.4 ^e	0.8 ^e	31 ^e	40.8	4.6	23			

^a March data were from the year following birth of each cohort.

^b Sample areas were located either east or west of the Sagavanirktok River.

^c Excluding 10 calves that were not considered neonatal based on the absence of umbilicus and appearance of hooves.

^d Calf weights include both males and females, mean weight was similar between sexes.

^e Excluding 1 calf that was not considered neonatal based on the absence of umbilicus and appearance of hooves.

TABLE 2 Change in weights (kg) of calves from the Central Arctic caribou herd, June–March 2001–2003

Area	Cohort	June–September			September–March ^a			June–March ^a		
		\bar{x}	s	n	\bar{x}	s	n	\bar{x}	s	n
East ^b	2001	34.6	3.9	24	6.7	2.6	11	40.9	5.8	11
	2002	36.2	3.7	24	2.9	1.5	10	39.2	4.4	10
	2003	39.0	3.7	23						
West ^b	2001	32.6	3.9	24	5.4	3.8	13	38.0	3.5	14
	2002	34.8	5.6	26	2.2	1.5	14	38.3	3.3	15
	2003	34.3	4.2	23						

^a March data were from the year following birth of each cohort.

^b Sample areas were located either east or west of the Sagavanirktok River.

TABLE 3 Metatarsus lengths (cm) of calves from the Central Arctic caribou herd, June–March 2001–2003

Area	Cohort	June			September			March ^a		
		\bar{x}	s	n	\bar{x}	s	n	\bar{x}	s	n
East ^b	2001	25.9	1.2	33	33.0	1.0	24	35.4	1.2	11
	2002	25.6 ^c	1.7 ^c	20 ^c	33.1	1.4	24	35.4	0.9	10
	2003	26.1	1.1	29	33.3	1.0	23			
West ^b	2001	25.6	1.6	32	32.7	1.2	24	35.3	1.3	14
	2002	25.4	0.9	30	32.6	1.3	26	35.0	0.7	15
	2003 ^d	25.3 ^e	1.0 ^e	31 ^e	32.9	0.7	23			

^a March data were from the year following birth of each cohort.

^b Sample areas were located either east or west of the Sagavanirktok River.

^c Excluding 10 calves that were not considered neonatal based on the absence of umbilicus and appearance of hooves.

^d Calf weights include both males and females, mean weight was similar between sexes.

^e Excluding 1 calf that was not considered neonatal based on the absence of umbilicus and appearance of hooves.

TABLE 4 Change in metatarsus lengths (cm) of calves from the Central Arctic caribou herd, June–March 2001–2003

Area	Cohort	June–September			September–March ^a			June–March ^a		
		\bar{x}	s	n	\bar{x}	s	n	\bar{x}	s	n
East ^b	2001	6.9	1.0	24	2.5	0.7	11	9.1	1.1	11
	2002	7.1	1.2	24	2.5	1.1	10	9.5	0.8	10
	2003	7.2	1.0	23						
West ^b	2001	6.8	1.2	24	2.7	1.6	13	9.2	1.7	14
	2002	7.1	1.0	26	2.3	1	14	9.4	0.6	15
	2003	7.5	1.0	23						

^a March data were from the year following birth of each cohort.

^b Sample areas were located either east or west of the Sagavanirktok River.

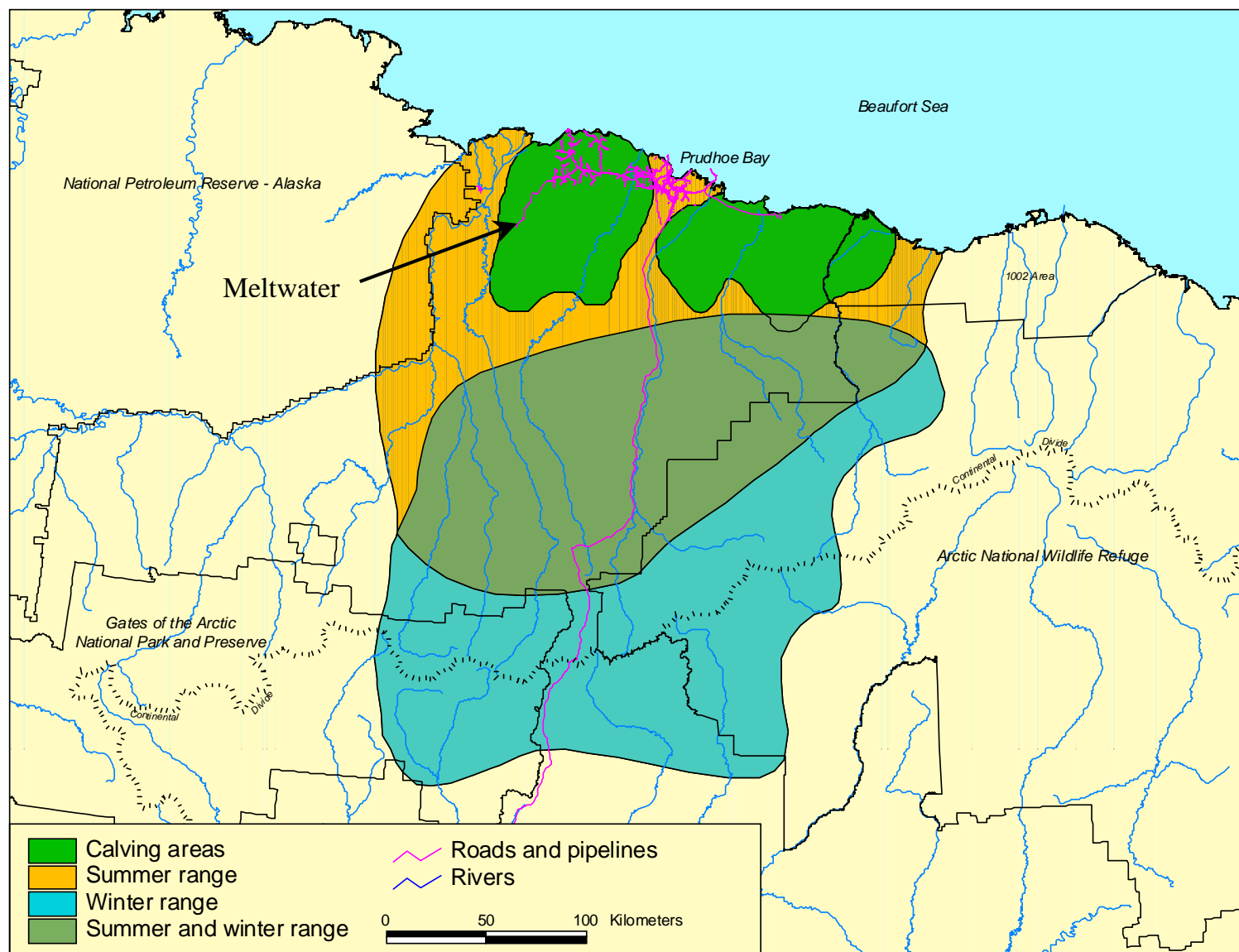


FIGURE 1 Seasonal ranges of the Central Arctic caribou herd

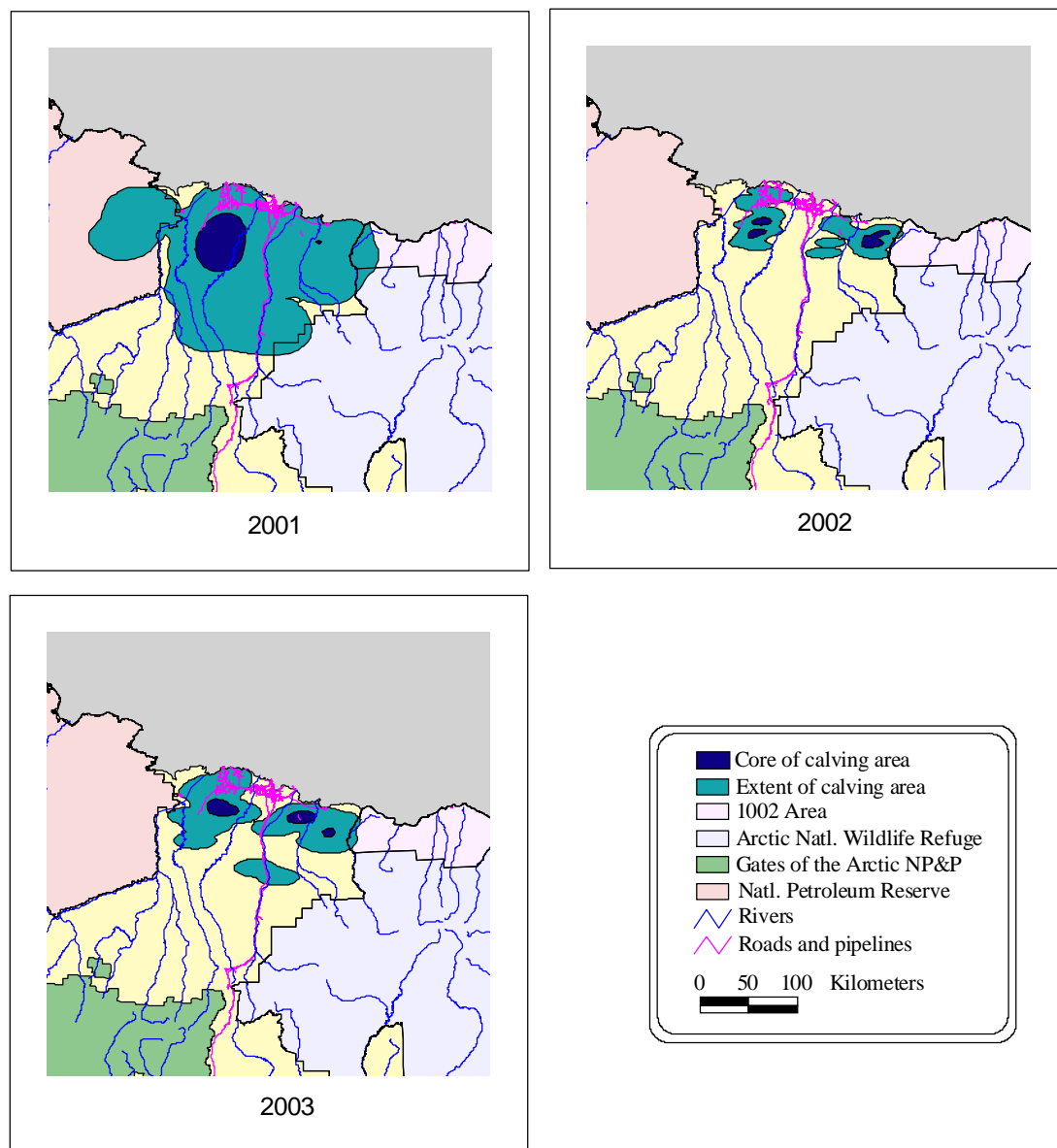


FIGURE 2 Distributions of parturient caribou cows during the peak of calving, 2001–2003. Extent of calving is defined by the 99% fixed kernel utilization distribution. Core areas are those with greater than average density of calving caribou; these encompassed 61–74% of the utilization distributions each year.

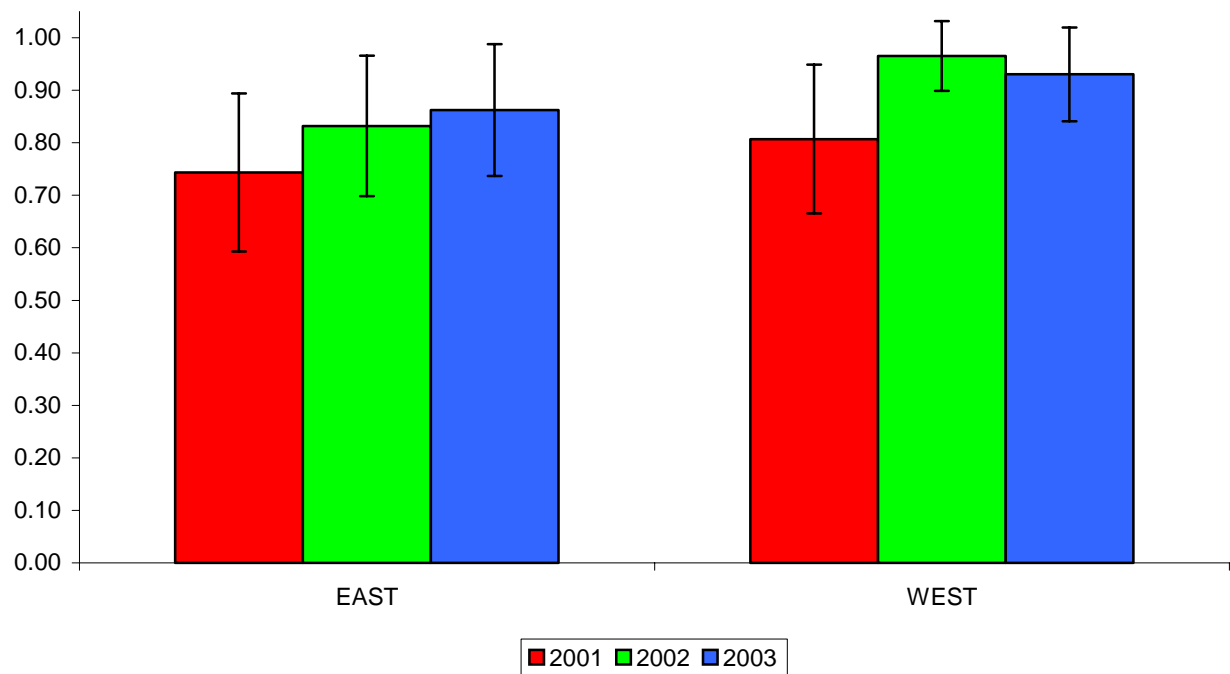


FIGURE 3 Survival rates of radiocollared Central Arctic caribou calves from calving areas either east or west of the Sagavanirktok River during June–September 2001–2003. Vertical lines indicate 95% confidence intervals.

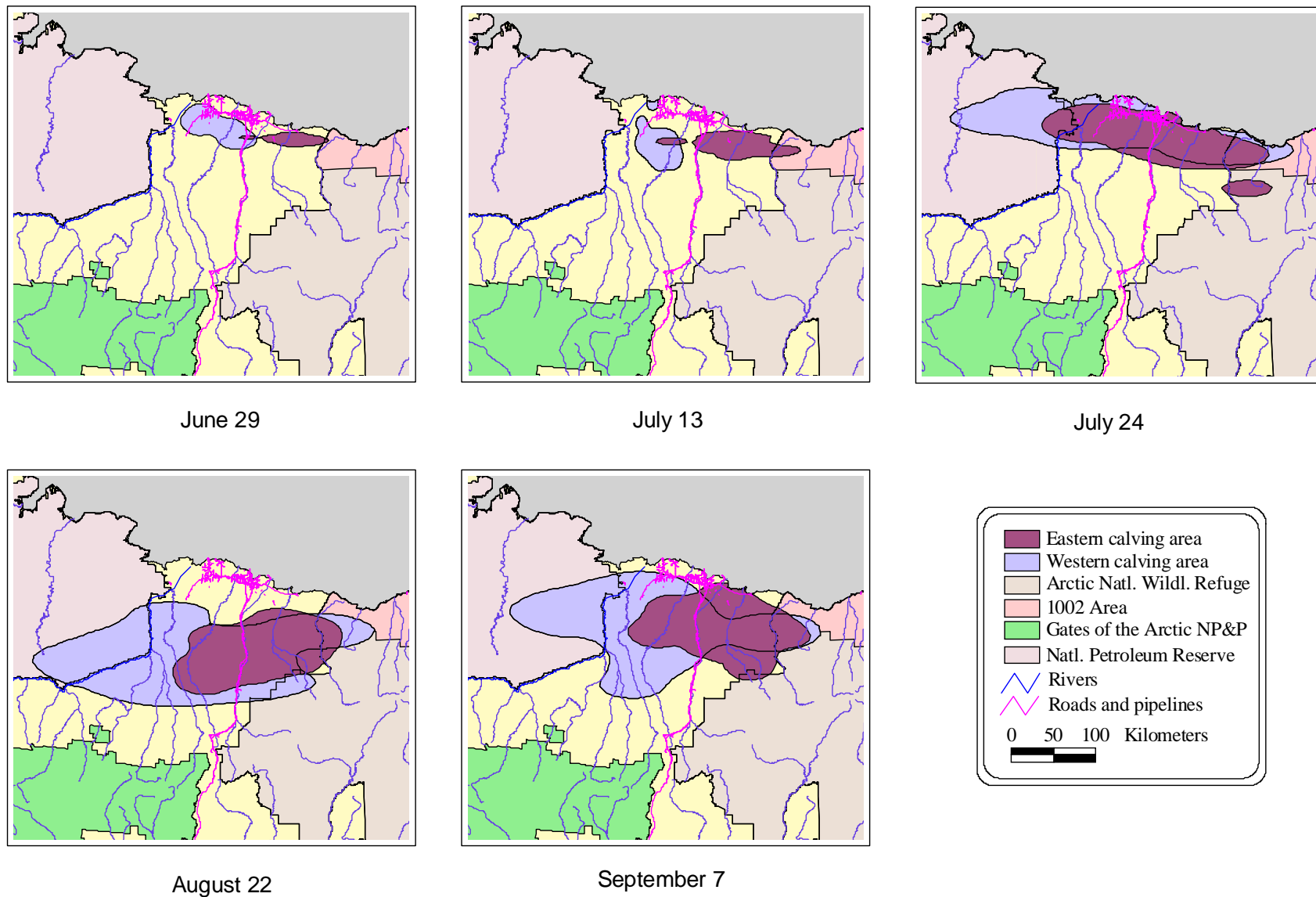


FIGURE 4 Distributions of radiocollared Central Arctic caribou calves during summer 2001. Colors indicate whether calves were born either east (purple) or west (blue) of the Sagavanirktok River. Distributions are based on the 95% fixed kernel utilization distributions of calf locations each day.

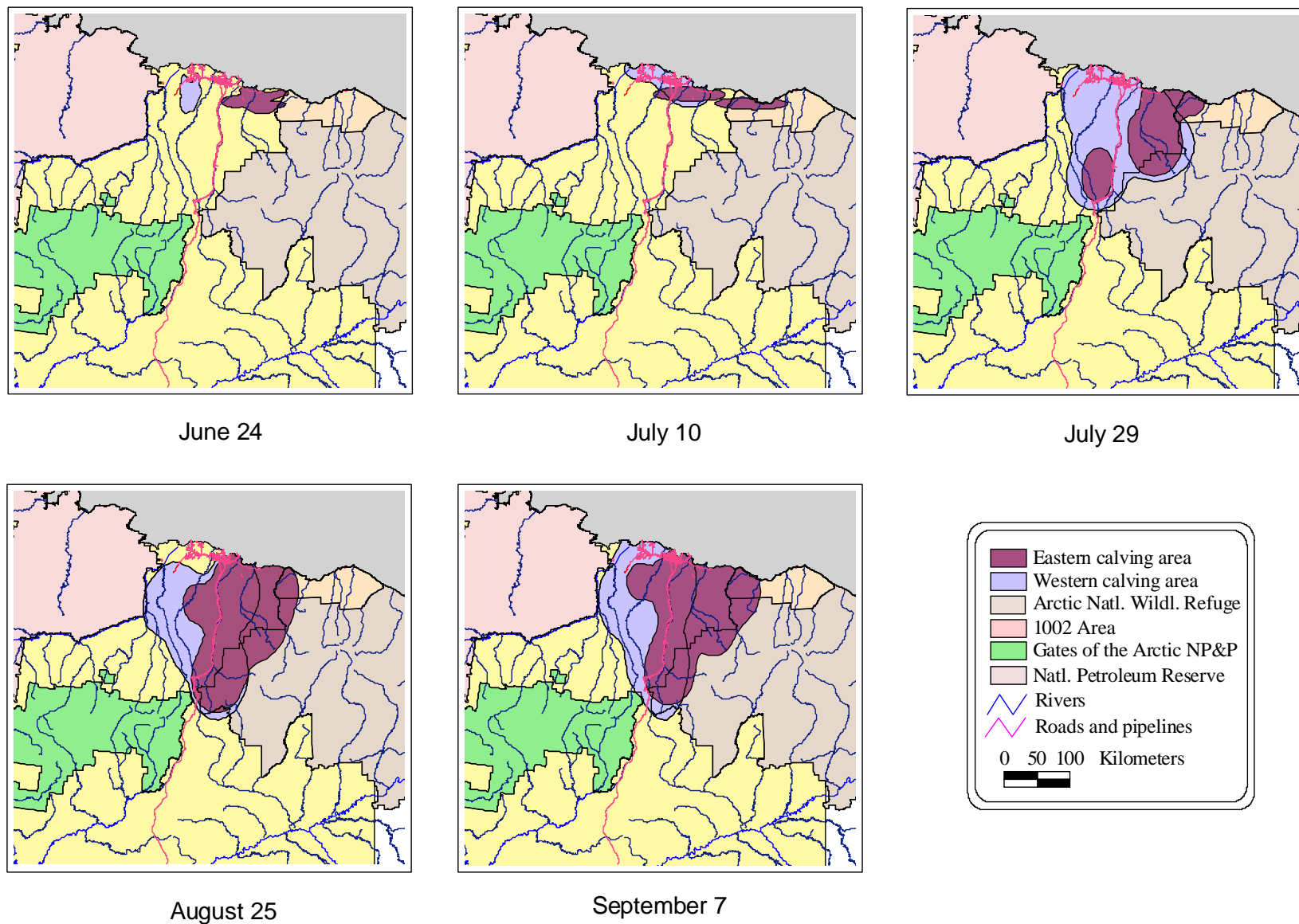


FIGURE 5 Distributions of radiocollared Central Arctic caribou calves during summer 2002. Colors indicate whether calves were born either east (purple) or west (blue) of the Sagavanirktok River. Distributions are based on the 95% fixed kernel utilization distributions of calf locations each day.

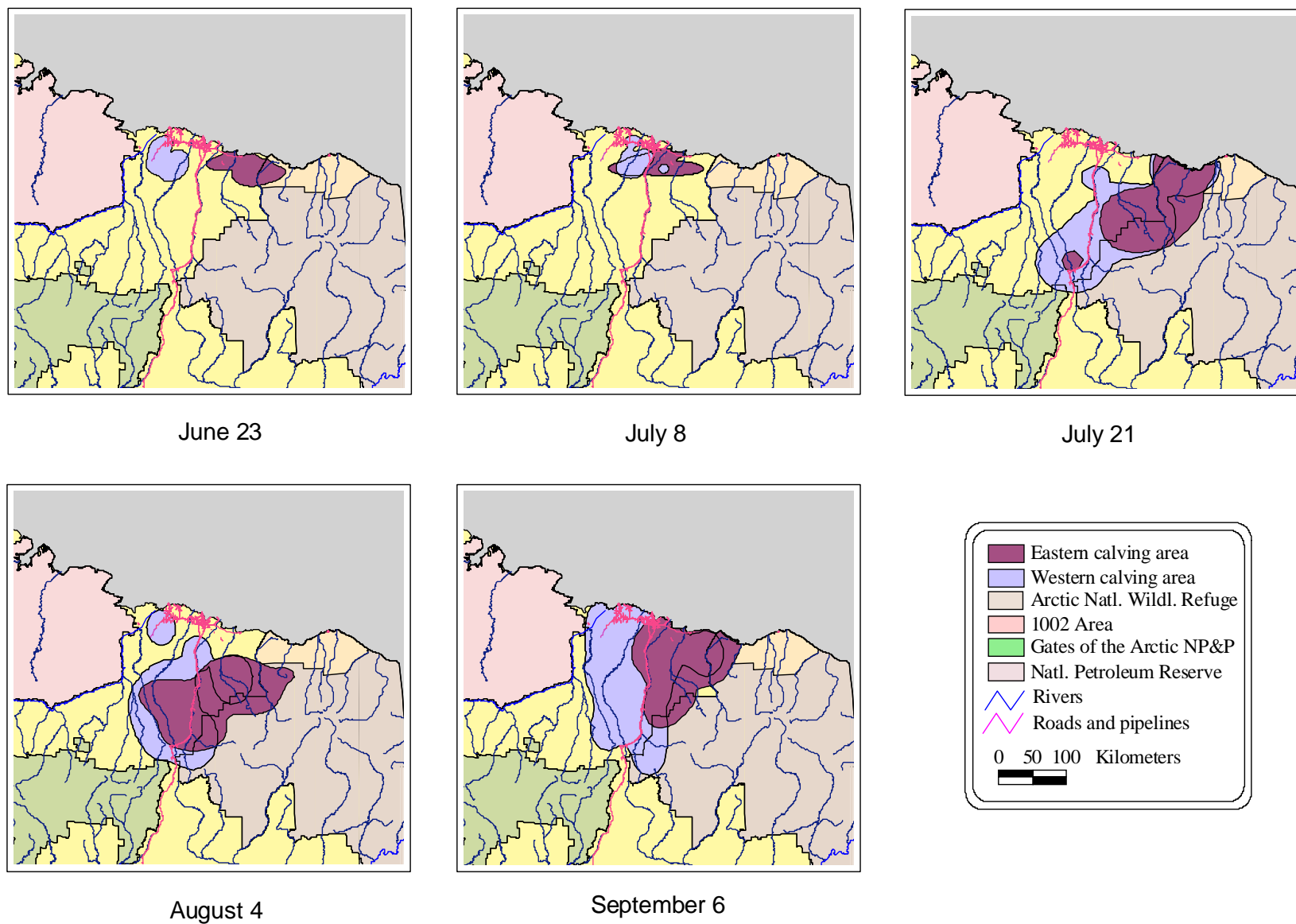


FIGURE 6 Distributions of radiocollared Central Arctic caribou calves in summer 2003. Colors indicate whether calves were born either east (purple) or west (blue) of the Sagavanirktok River. Distributions are based on the 95% fixed kernel utilization distributions of calf locations each day.

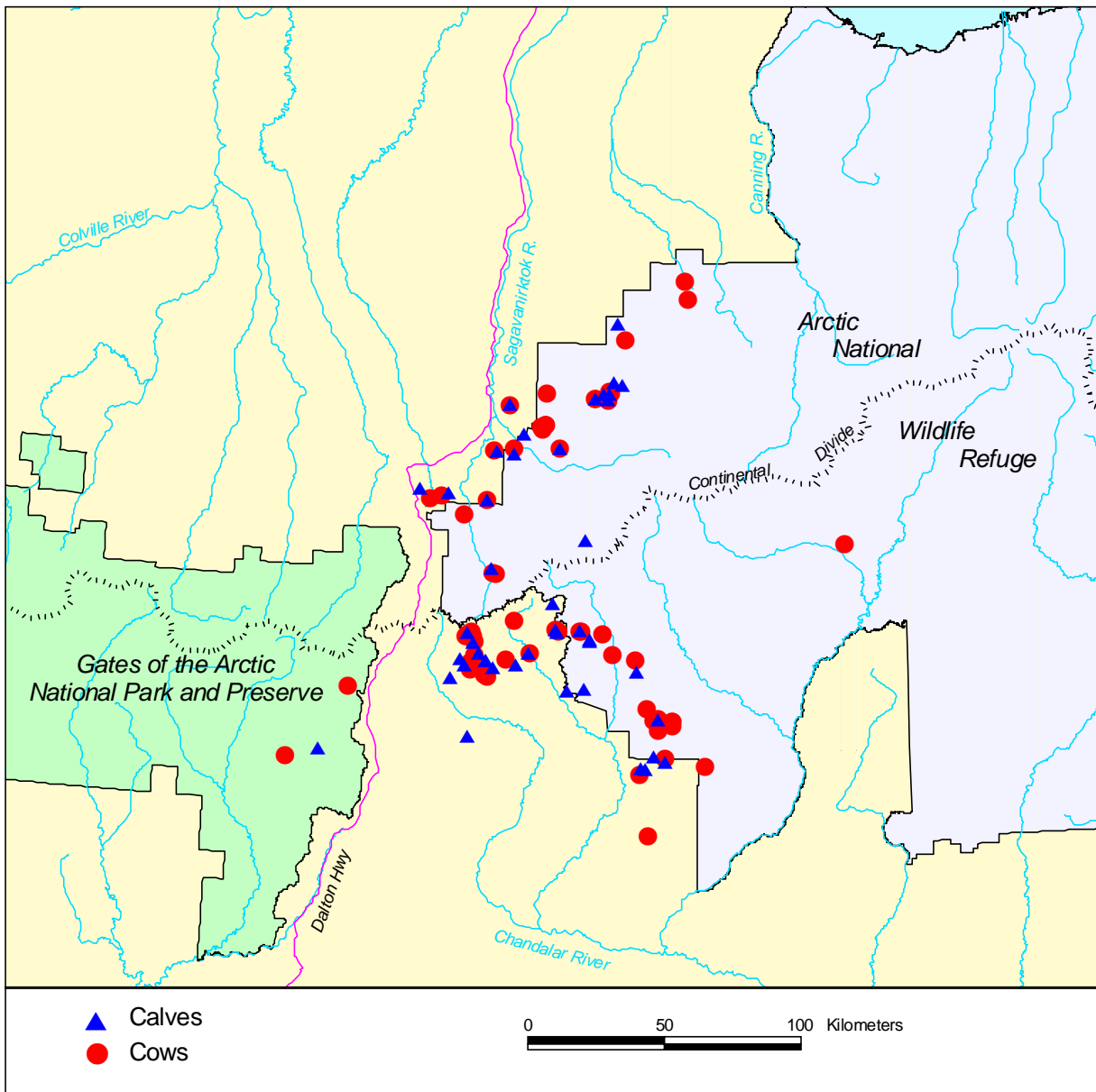


FIGURE 7 Distribution of radiocollared caribou from the Central Arctic Herd, February–March 2002

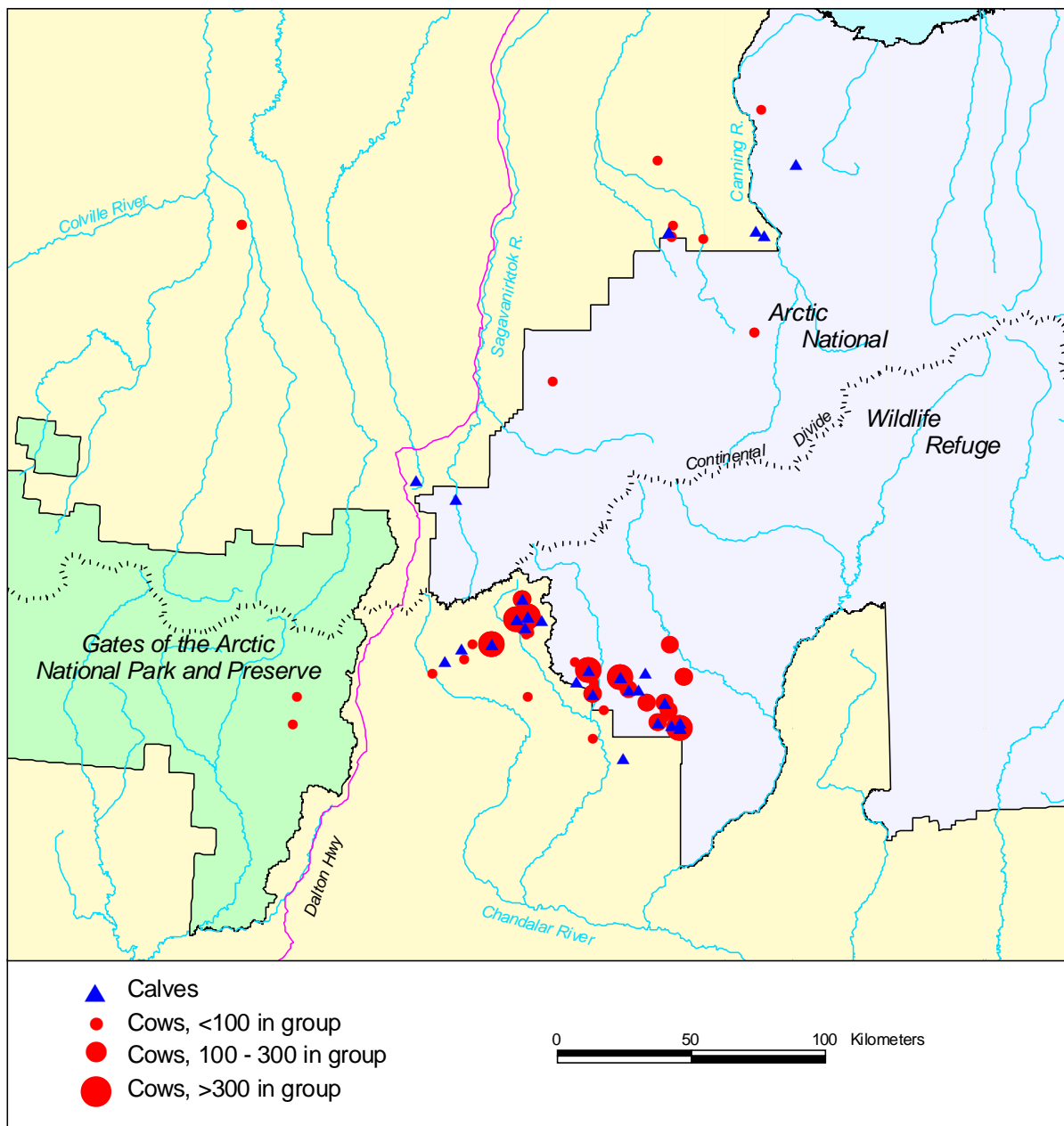


FIGURE 8 Distribution of radiocollared caribou from the Central Arctic Herd, February–March 2003

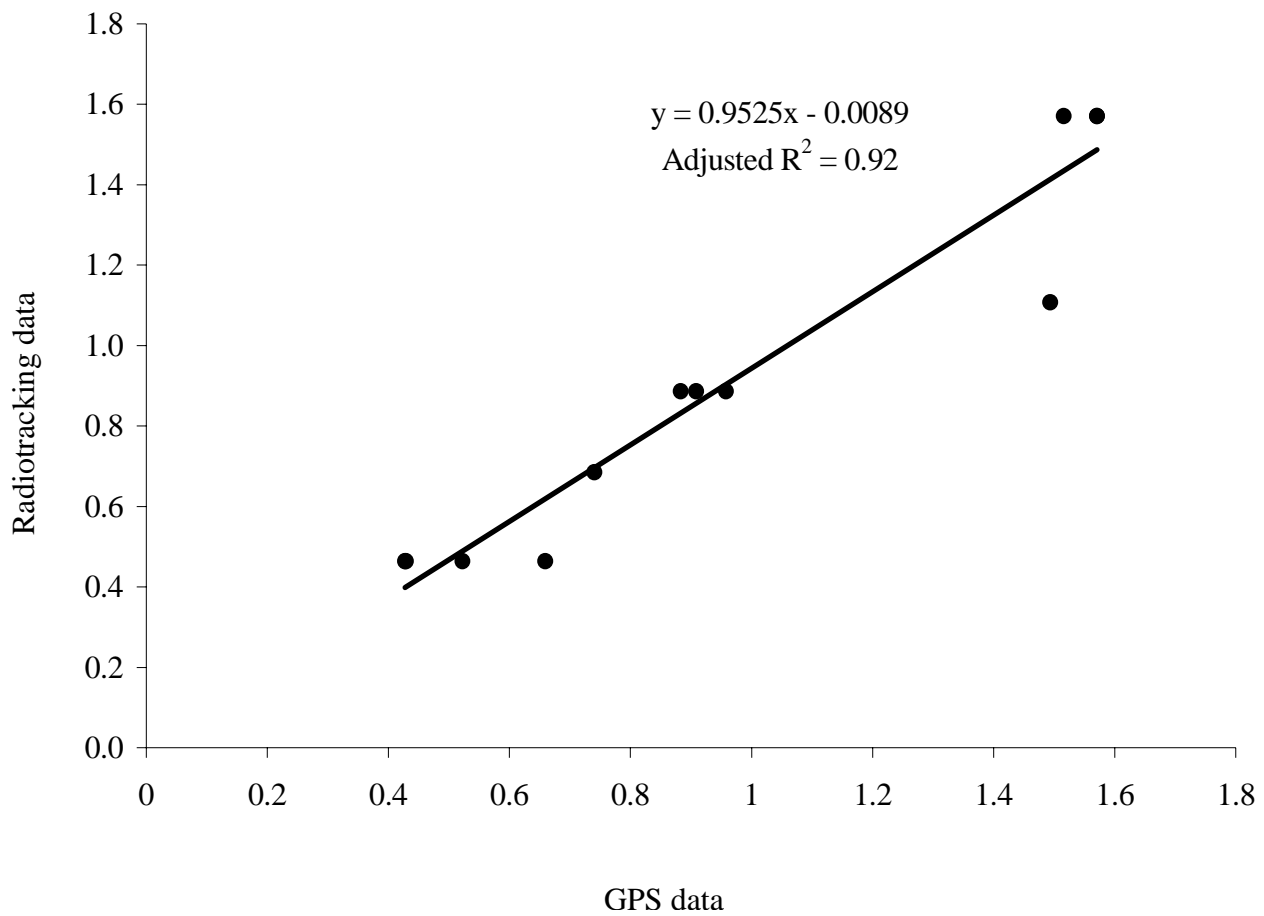


FIGURE 9 Arc-sine transformation of percent of locations of radiocollared calves that were east of the Sagavanirktok River, June–September 2003. Locations were determined by radiotracking at approximately 2-week intervals or by GPS collars programmed to obtain locations every 5 hours